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PROBLEM ANALYSIS

# TREE PHYSIOLOGY IN RELATION TO SOUTHERN PINE BARK BEETLES

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## Introduction

The foundation for this analysis was prepared by F. W. Whitmore, plant physiologist, in September, 1964, prior to his resignation from the Forest Service. His proposals were made to circumscribe the general area in which the plant physiologist at the Alexandria Forest Insect Research Project should concentrate. No specific future studies were suggested by Whitmore on the grounds that "a proposal of future studies must await availability of laboratory facilities and equipment and the direction of entomological research to be undertaken by R. C. Thatcher," who at the time was on educational leave

The format of Whitmore's analysis has been completely reorganized, the contents have been expanded and updated, and some specific studies and their priorities have been added. For the most part, Whitmore's proposals have been incorporated in this analysis.

## The Problem

Major epidemics of the southern pine beetle recur at irregular intervals in the same stands in well-defined areas of some states but not in others. In the Midsouth, for example, these areas are in the flatwoods of southeast Texas and southwest Louisiana, the rolling-hill country of southwest Mississippi and west-central Alabama, and the mountains of northern Alabama. The complex factors that are associated with epidemics

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1/ Limited presently to the southern pine beetle. As expediency dictates inclusion of other bark beetles, this analysis will be so revised.

on these diverse sites are unknown. Nor is it known whether the same factor complex is common to all trouble areas or whether factors contributing to epidemics vary within any one area from one outbreak to another.

The problem is to find the cause or causes of these outbreaks in order to effect a cure. It involves determining tree physiological changes that are related to tree vigor, especially changes that take place within phloem tissue, and the relationship of these changes to insect attack and survival. Some of the factors believed to affect the insect through tree physiological changes are extremes in soil moisture, particularly in relation to site, stand mixture, and density; tree age and dominance; and lightning damage. Other factors that may directly or indirectly affect the insect are seasonal physiological changes within the tree, the tree's water regime in relation to fungi and other microorganisms associated with the beetle, and loss of tree vigor as a result of root damage by soil fungi and nematodes.

Also related to the problem and of prime importance to future research in plant physiological aspects of beetle epidemics, is the need for information on the nutritional, spatial, temperature, and moisture requirements of the insect. This research is in the realm of the insect physiologist and ecologist and investigations in this area are being made by E. W. Clark, Southeastern Forest Experiment Station, and by S. J. Barras and R. C. Thatcher, Southern Forest Experiment Station. Clark is working on nutritional requirements of insect development on artificial media. Barras (1966) is concerned

with the nutritional aspects of yeasts and fungi associated with bark beetles, and Thatcher (1965) is studying the effect of oleoresin vapors as related to beetle attack.

Until a knowledge of microenvironmental requirements of the insect is obtained, studies in plant physiology will have to be correlative and somewhat restricted. Thus, as developments in insect physiology unfold, this analysis will need to be revised and expanded to incorporate new lines of approach and study priorities.

## Existing Knowledge

R. C. Hare, Southern Institute of Forest Genetics, is the only plant physiologist other than Hodges currently at work on bark beetle problems in the South. He has prepared a thorough literature review of the general aspects of insect host selection and plant resistance to insect activity, as well as a problem analysis (1964). Hare's analysis and proposals for research are primarily devoted to isolation and identification of natural chemical attractants, arrestants, and repellants produced in trees, and with the possible utilization of results from these investigations in the propagation of resistant trees. Hare is working closely with J. F. Coyne, who has been concentrating on the terpene constituents in pines in terms of their function in insect resistance and their hereditability.

The approach being taken by researchers at the Alexandria Forest Insect Project is to find what conditions in trees and stands, including site, permit the buildup and maintenance of epidemic populations. The fact that beetle epidemics recur in certain areas has led

to the belief that soils may be implicated. Lorio (1963) already has found that a large proportion of southern pine beetle group attacks over a large area in east Texas took place on similar soils.

The influence of soils on tree susceptibility to beetle attack must be interpreted in terms of plant physiology. Both the chemical and physical properties of soils influence the physiological processes of forest trees. Most of the work in the relationship of soil chemistry to tree physiology has been concerned with the availability of essential nutrients. At first glance, the chemical properties of the soils in areas of recurring beetle epidemics appear to be unrelated to tree susceptibility because of the frequently excellent average annual growth of the stands involved. Much of the current beetle damage in southwestern Louisiana has occurred in stands having a site index of 100-110 feet at 50 years. These observations do not preclude the involvement of soil chemical properties, however. It is possible that soils associated with chronic trouble areas are deficient in some substances important in a possible beetle defense mechanism, but that this deficiency has no effect on growth.

The physical characteristics of these soils, especially in their role in plant-water relationships and root distribution, may be of great importance in the forest-beetle complex, however. Some effects of water stress on general physiological processes have been discussed by Kramer (1962). They include reduction of photosynthesis, reduction of carbohydrate translocation, and reduction of cell division.

Phloem moisture content is reduced, which may favor beetle brood development (Craighead, 1925; Dixon and Osgood, 1961). Moisture stress apparently reduces oleoresin pressure (Munch, 1918; Vité, 1961), and may alter the form of carbohydrates transported in the phloem sap (Roberts, 1963). None of these effects has definitely been shown to influence bark beetle population; although hypotheses have implicated some of them.

Whitmore and Lorio (1964, 1965) completed a preliminary short-term study on the effects of controlled soil moisture on oleoresin exudation pressure, phloem constituents, and the water balance in young loblolly pine. Refinement and analysis of data were hampered by a lack of laboratory facilities and equipment which existed prior to Whitmore's leaving. A similar study by Lorio and Hodges (1965), with modifications based on experience of the previous study, is in the initial stages. The general objective is to find what physiological changes occur in the phloem of large trees under widely differing moisture stress and in an active beetle outbreak area.

## Research Attack Proposed

There are two separate but somewhat overlapping areas of research in tree-insect relationships which are in the province of plant physiology. One is the basic mechanism of attraction and repulsion residing in the insect but operating through the chemistry of the plant. The objectives of research in this area would be, in addition to a fuller understanding of the biological details, the development of

control methods based on attractants and repellants, and the propagation of resistant trees. Hare has covered these objectives in his problem analysis, and has proposed studies directed toward them.

The second area of research is concerned with conditions in trees and stands which permit the buildup and maintenance of epidemic populations of beetles. This area may possibly overlap with the first insofar as trees which are unable to resist beetle attack may produce volatile attractants. At present this phenomenon is only speculative. It seems certain, however, that the forest complex, including beetles, can undergo occasional changes which permit destructive beetle populations to occur.

Further, the quantative aspects of brood development must be examined in relation to the physiological condition of the tree. The ratio of increase in population is crucial and seems to be variable with season and with host condition. The brood production in trees struck by lightning appears to be much higher than the average in other trees in the same stand and at the same time of the season. The factors causing such an unusually high ratio may be separate and distinct from a possible volatile attractant produced by lightning strike. These factors may be a more favorable inner bark moisture content or an improved nutrient substrate caused by the strike. Of additional interest is the fact that during periods of low beetle activity, i.e. late summer, the insects seem to occur primarily in lightning-struck trees.

The plant physiologist also must utilize information supplied by workers in insect physiology, ecology, and phytopathology to delimit the plant factors that work against or favor the insect. These factors may operate through their influence on soil fungi, fungi and other microorganisms associated with beetle galleries, and other microorganisms such as mites and insect enemies of the beetle. For example, there is much speculation concerning the relationship between the beetle and certain fungi. It is possible that a symbiotic relationship exists and that the fungi provide the beetle with certain necessary factors (e. g. vitamins or amino acids). Therefore, it is desirable to know what effect the tree has on the fungi, and also what changes the fungi cause in the physiology of the tree.

The objectives of tree physiological research will be to provide a better understanding of basic ecological relationships among soils, trees, and beetles. Practical implications may be improvements in silvicultural practices in existing, susceptible stands, and perhaps as important, the prediction of epidemics in present or potential trouble areas.

Studies Indicated and Their Priorities

1. Physiological changes in plant tissue in response to soil moisture regime. This study has been initiated in the flatwoods of central Louisiana. It should eventually be undertaken in the rolling-hill country of Mississippi, and, finally, the mountains of northern Alabama.

2. Physiological factors in lightning-struck trees in relation to bark beetle attack and development. Lightning strikes probably never are frequent enough to explain epidemic buildup; however, the same sort of changes that develop in lightning-struck trees may occur in many trees through other stress conditions, leading to epidemic populations. Lightning-struck trees, also, may be useful in determining the probable factors leading to high ratios of beetle increase. A study plan has been submitted.

3. Production of carbonyl compounds by blue-stain fungi in culture and in natural hosts. A study plan (Barras and Hodges, 1966) is being prepared. The objective of the study will be to determine the possible carbonyl compounds produced by blue-stain fungi in association with the southern pine beetle. These compounds may serve as attractants for the beetle.

4. An investigation into the level of nitrogen compounds in the phloem tissue of lightning-struck trees. This is a proposed cooperative study with Northwestern Louisiana State College. The proposal has been submitted.

5. A study of soil, soil fungi, and root conditions associated with a loblolly pine decline similar to littleleaf disease. Purpose will be to determine the reason for the decline and the extent of association of these trees with bark beetle attacks. Affected trees may be more susceptible to bark beetle attack and could enhance maintenance and build-up of the beetle population.

6. Changes, over a period of time, in carbohydrates and nitrogen compounds in the vicinity of bark beetle galleries. These changes may be influenced by microorganisms, e. g. blue-stain fungi and yeasts, and may influence beetle development.

7. Seasonal changes in the pattern of attack by the southern pine beetle. Level of attack (height) on tree, size of brood produced, and length of time from attack to brood emergence may be influenced by factors of tree physiology.

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